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U.S. PATENT APPLICATION

for

METHOD OF ENHANCING CLEAR FIELD PHASE SHIFT MASKS WITH CHROME BORDER AROUND PHASE 180 REGIONS

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CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is related to U.S. Patent Application No. ___________, Attorney Docket No. 39153/447 (G1152), entitled METHOD OF EXTENDING THE AREAS OF CLEAR FIELD PHASE SHIFT GENERATION; U.S. Patent Application No. ___________, Attorney Docket No. 39153/449 (G1154), entitled METHOD OF ENHANCING CLEAR FIELD PHASE SHIFT MASKS BY ADDING PARALLEL LINE TO PHASE 0 REGION; U.S. Patent Application No. ___________, Attorney Docket No. 39153/450 (G1155), entitled METHOD OF ENHANCING CLEAR FIELD PHASE SHIFT MASKS WITH BORDER REGIONS AROUND PHASE 0 AND PHASE 180 REGIONS; and U.S. Patent Application No. ___________, Attorney Docket No. 39153/451 (G1156), entitled METHOD OF ENHANCING CLEAR FIELD PHASE SHIFT MASKS WITH BORDER AROUND OUTSIDE EDGES OF PHASE ZERO REGIONS, all of which are assigned to the same assignee as the present application.

FIELD OF THE INVENTION

[0002] The present invention relates generally to integrated circuits and methods of manufacturing integrated circuits. More particularly, the present invention relates to generating phase shifting patterns to improve the patterning of gates and other layers, structures, or regions needing sub-nominal dimensions.

BACKGROUND OF THE INVENTION

[0003] Semiconductor devices or integrated circuits (ICs) can include millions of devices, such as, transistors. Ultra-large scale integrated (ULSI) circuits can include complementary metal oxide semiconductor (CMOS) field effect transistors (FET). Despite the ability of conventional systems and processes to fabricate millions of IC devices on an IC, there is still a need to decrease the size of IC device features, and, thus, increase the number of devices on an IC.

[0004] One limitation to achieving smaller sizes of IC device features is the capability of conventional lithography. Lithography is the process by which a pattern or image is transferred from one medium to another. Conventional IC lithography uses ultra-violet (UV) sensitive photoresist. Ultra-violet light is projected to the photoresist through a reticle or mask to create device patterns on an IC. Conventional IC lithographic processes are limited in their ability to print small features, such as contacts, trenches, polysilicon lines or gate structures.

[0005] Generally, conventional lithographic processes (e.g., projection lithography and EUV lithography) do not have sufficient resolution and accuracy to consistently fabricate small features of minimum size. Resolution can be adversely impacted by a number of phenomena including: diffraction of light, lens aberrations, mechanical stability, contamination, optical properties of resist material, resist contrast, resist swelling, thermal flow of resist, etc. As such, the critical dimensions of contacts, trenches, gates, and, thus, IC devices, are limited in how small they can be.

[0006] For example, at integrated circuit design feature sizes of 0.5 microns or less, the best resolution for optical lithography

technique requires a maximum obtainable numerical aperture (NA) of the lens systems. Superior focus cannot be obtained when good resolution is obtained and vice versa because the depth of field of the lens system is inversely proportional to the NA and the surface of the integrated circuit cannot be optically flat. Consequently, as the minimum realizable dimension is reduced in manufacturing processes for semiconductors, the limits of conventional optical lithography technology are being reached. In particular, as the minimum dimension approaches 0.1 microns, traditional optical lithography techniques may not work effectively.

[0007] With the desire of reducing feature size, integrated circuit (IC) manufacturers established a technique called "phase shifting." In phase shifting, destructive interference caused by two adjacent translucent areas in an optical lithography mask is used to create an unexposed area on the photoresist layer. Phase shifting exploits a phenomenon in which light passing through translucent regions on a mask exhibits a wave characteristic such that the phase of the light exiting from the mask material is a function of the distance the light travels through the mask material. This distance is equal to the thickness of the mask material.

[0008] Phase shifting allows for an enhancement of the quality of the image produced by a mask. A desired unexposed area on the photoresist layer can be produced through the interference of light from adjacent translucent areas having the property that the phase of the light passing through adjacent apertures is shifted by 180 degrees relative to each other. A dark, unexposed area will be formed on the photoresist layer along the boundary of the phase shifted areas caused by the destructive interference of the light which passes through them.

[0009] Phase shifting masks are well known and have been employed in various configurations as set out by B. J. Lin in the article, "Phase-Shifting Masks Gain an Edge," Circuits and Devices, March 1993, pp. 28-35. The configuration described above has been called alternating phase shift masking (PSM).

[0010] In some cases, phase shifting algorithms employed to design phase shifting masks define a phase shifting area that extends just beyond active regions of an active layer. The remaining length of polysilicon, for example, is typically defined by a field or trim mask. However, this approach is not without its problems. For example, alignment offsets between phase shift masks and field masks may result in kinks or pinched regions in the polysilicon lines as they transition from the phase shifting area to the field mask areas. Also, since the field masks are employed to print the dense, narrow lines of polysilicon beyond the active regions, the field masks become as critical and exacting as the phase shift masks.

[0011] Phase shift patterning of polysilicon or "poly" layouts has been proven to be an enhancement in both manufacturing as well as enabling smaller patterned lines and narrow pitches. These items can be more enhanced as the desired linewidth and pitch shrinks, yet there can be some risks and complications.

[0012] Conventional patterning with phase shifters has been done by shifting only the areas of minimum desired dimensions—usually the poly gate or narrow poly that is over the active pattern. The patterned poly lines that are away from the active regions are usually laid out with similar design rules as that of the patterned poly lines on active regions. As such, there can be many transitions between the phase

shifted patterning and binary patterning. Transition areas can result in linewidth loss, increasing device leakage.

[0013] Current alternating phase shift masking (PSM) designs for polysilicon layers often focus on enabling gate shrink by applying alternating phase shift regions around the gate region (i.e., the intersection of the polysilicon and active layers). One such alternating PSM design is described in U.S. Patent No. 5,573,890 entitled METHOD OF OPTICAL LITHOGRAPHY USING PHASE SHIFT MASKING, by Christopher A. Spence (one of the inventors of the present application) and assigned to the assignee of the present application.

[0014] An enhanced phase shift approach was developed to reduce the transition regions and move those regions away from the active edge to wider poly or corners of poly patterns where linewidth loss would have little or no impact. Examples of this enhanced phase shifting approach are described in U.S. Patent Application Serial No. ____________, entitled PHASE SHIFT MASK AND SYSTEM AND METHOD FOR MAKING THE SAME, filed on January 30, 2001, by Todd P. Lukanc (one of the inventors of the present application) and assigned to the assignee of the present application, incorporated herein by reference.

[0015] The specification of the Lukanc patent application describes binary and phase masks that define parts of the poly pattern and need to have very controlled critical dimensions (CDs). The phase mask basically has long narrow openings that are easy to pattern but the binary mask has both small openings as well as small lines, in both isolated and dense areas. As such, the patterning of the binary mask can be complicated and the manufacturing window of this technique can be limited. In both the simple phase and the enhanced phase methods, both

masks are critical and have different optimized illumination and patterning conditions.

[0016] Other known systems use a "node" based approach rather than a gate-specific approach to generate a phase assignment that attempts to apply phase shifting to all minimum poly geometries (both field and gate). Two examples of the "node" based approach include, for example, Galan et al. "Applications of Alternating-Type Phase Shift Mask to Polysilicon Level for Random Logic Circuits," Jpn. J. Appl. Phys. Vol. 33 (1994) pp. 6779-6784, Dec. 1994, and U.S. Patent No. 5,807,649 entitled LITHOGRAPHIC PATTERNING METHOD AND MASK SET THEREFOR WITH LIGHT FIELD TRIM MASK, by Liebmann et al.

[0017] In view of the known art, there is a need for improvements to the clear field phase shifting mask (PSM) and field or trim mask approach that result in simpler and more reliable mask fabrication and in better wafer imaging. Further, there is a need to minimize variations or use of optical proximity correction (OPC) by enclosing phase shift masking features. Yet further, there is a need to generate phase shifting patterns to improve the patterning of gates and other layers needing sub-nominal dimensions.

SUMMARY OF THE INVENTION

[0018] An exemplary embodiment is related to enhancing clear field phase shift masks using a chrome border around first phase regions. An exemplary method involves identifying edges of a first phase pattern, expanding these edges, and merging the expansions with chrome. An alternative method involves oversizing and undersizing first phase data, taking the difference, and merging the difference with

chrome. The chrome region on the phase mask can improve mask generation by allowing the chrome on the mask to fully define the quartz etch.

[0019] Another exemplary embodiment is related to a method of designing a phase shifting mask for use in the fabrication of integrated circuits. The method can include identifying edges of a first phase region of a phase shifting mask, expanding the identified edges to define a narrow line along the edges of the first phase region, and forming chrome in the narrow line to form a chrome boundary along the edges of the first phase region. The first phase region is generally located proximate a critical region, such as, critical poly or other region desired to be defined by phase shifting and the identified edges are not edges of the first phase region adjacent to the critical region.

[0020] Another exemplary embodiment is related to a method of generating phase shifting patterns to improve the patterning of gates and other layers needing sub-nominal dimensions. This method can include defining critical gate areas, creating phase areas on either side of the critical gate areas, assigning opposite phase polarities to the phase areas on either side of the critical gate areas, enhancing phase areas with assigned phase polarities, defining break regions where phase transitions are likely to occur, generating polygons to define other edges and excluding the defined break regions, and constructing a boundary region outside of first phase regions to form a chrome border.

[0021] Another exemplary embodiment is related to a method of enhancing clear field phase shift masks with a chrome border around outside edges of a first phase area. This method can include assigning phase polarities to phase areas where the phase areas include first phase areas and second phase areas, defining edges of the assigned

phase areas, establishing a boundary around the defined edges of the first phase areas, and forming a chrome border in the boundary around the first phase area.

[0022] Another exemplary embodiment is related to a mask configured for use in an integrated circuit manufacturing process. This mask can include a critical pattern section defined by first edges of a phase zero region and first edges of a phase 180 region and a chrome boundary region located outside second edges of the phase 180 region. The second edges of the phase 180 region are different than the first edges of the phase 180 region. The chrome boundary region includes an opaque material.

[0023] Other principle features and advantages of the invention will become apparent to those skilled in the art upon review of the following drawings, the detailed description, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The exemplary embodiments will hereafter be described with reference to the accompanying drawings, wherein like numerals denote like elements, and:

[0025] FIGURE 1 is a flow diagram illustrating steps in a method of forming a phase shift mask according to an exemplary embodiment;

[0026] FIGURE 2 is a top planar view of a phase shift mask design in accordance with an exemplary embodiment;

[0027] FIGURE 3 is a top planar view of a field or trim mask design configured for use with the phase shift mask design of FIGURE 2 in accordance with an exemplary embodiment; and

[0028] FIGURE 4 is a block illustration of a portion of a poly line separating a phase 180 region and a phase 0 region and a corresponding trim mask in accordance with an exemplary embodiment.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0029] FIGURE 1 illustrates a flow diagram 100 depicting exemplary steps in the formation or design of a phase shifting mask (PSM) and a field or trim mask. A set of previously defined phase 0 or phase 180 regions on a phase mask help identify a critical poly section. These phase 0 or phase 180 regions can be created by hand drawing, by using a currently available software program, or by creating an optimized program to define the regions.

[0030] In a step 110, an opaque boundary region is formed on the phase mask outside phase 180 region edges of the previously defined phase 180 regions that are not defining a final poly pattern. This opaque boundary region can be defined by either hand drawing or by using a computer software program. Advantageously, the design database created by merging the defined opaque boundary region with the critical layer pattern can be used for "die-to-database" inspection, thereby simplifying the mask manufacturing process. In a step 120, all regions not defined (either as the final poly pattern or phase 180 regions or chrome boundary regions) are defined as phase 0.

[0031] In a step 130, the chrome is patterned and etched on the mask. As part of the chrome defining process or after the chrome

is patterned, a layer of resist is coated and sections of the resist are selectively removed in areas where phase 180 sections are to be formed. In an exemplary embodiment, an oversized phase 180 pattern, or a phase etch region, is defined to allow the resist to be removed and the quartz to be etched. This oversized resist pattern covers any openings in the chrome where it is desired to avoid etching. A dry or wet etch can be used to etch the quartz to a lesser thickness in the formation of the phase 180 regions. The formation of phase 180 sections and phase etch regions are further described with reference to FIGURE 2.

[0032] In a step 140, the trim mask is formed to have openings that are oversized versions of the boundary chrome regions outside the final poly pattern. The openings of the trim mask are oversized because their size is slightly larger in area than the boundary regions. In the trim masking process, the openings of the trim mask are placed over these slightly smaller boundary regions. An exemplary trim mask is described with reference to FIGURE 3.

[0033] FIGURE 2 illustrates a plan view of a phase mask 200 formed or designed utilizing the process described with reference to FIGURE 1. Phase mask 200 includes poly regions 210, phase 180 regions 220, phase 0 regions 230, and phase 180 boundary regions 240. Poly regions 210 (depicted in FIGURE 2 as dotted areas) are critical poly sections. Phase 180 regions 220 and phase 0 regions 230 help to define poly regions 210 and can be created by hand or using a computer software program configured for the designing of phase masks. Phase 180 boundary regions 240 can be formed outside edges of defined phase 180 regions 220 that are not defining the poly pattern.

[0034] Phase mask 200 also can include a region 250 outside of defined areas. In an exemplary embodiment, region 250

(depicted in FIGURE 2 as a gray back-hashed area) is assigned a phase of zero.

[0035] Phase etch regions 260 (depicted in FIGURE 2 using a bold dashed line) are areas that define a pattern used in the formation of phase 180 regions 220. Advantageously, the positions of phase etch regions 260 are self-aligned to the chrome pattern as to avoid misplacement of the etch pattern relative to the original chrome pattern. In an alternative embodiment, it is possible to make the etch profile such that it partially goes underneath the chrome to partially hide the etch profile. The partially hidden etch profile allows for some variation in sidewall profiles.

[0036] Trim mask openings 270 (depicted in FIGURE 2 using a dotted line) define an area that is exposed when the field or trim mask is applied. An exemplary trim mask corresponding to trim mask openings 270 is described with reference to FIGURE 3.

[0037] FIGURE 3 illustrates a plan view of a field or trim mask 300. Trim mask 300 is configured for use with phase mask 200 described with reference to FIGURE 2. Trim mask 300 includes openings 310 corresponding to trim mask opening 270 in FIGURE 2.

[0038] FIGURE 4 illustrates a poly line 400 and a trim mask 405. Poly line 400 separates a phase 180 region 410 and a phase 0 region 420. A chrome boundary 430 is located along edges of phase 180 region 410. Chrome boundary 430 can improve mask generation by allowing a chrome mask to fully define the quartz etch.

[0039] In an exemplary embodiment, chrome boundary 430 is formed by identifying edges of phase 180 region 410, expanding these edges outward and inward to define a narrow line, and forming

chrome in the narrow line. Chrome boundary 430 can have a width of approximately the minimum gate width dimension or the width between phase 0 and phase 180 regions where the critical gates are formed. Alternatively, chrome boundary 430 can be generated by considering the phase 180 data, oversizing and undersizing the data and taking the difference.

[0040] Exemplary materials for chrome boundary 430 can include any material of opaque qualities. Alternatively, other suitable opaque materials can be utilized for boundary 430, such as any material known to a person of skill in the art to satisfy necessary phase requirements.

[0041] Advantageously, chrome boundary 430 can improve the mask generation by allowing the chrome mask to fully define the quartz etch, making more repeatable etch profiles possible. Further, the chrome database used to write the phase mask can be used for die-to-database inspection. Yet further, although narrow, chrome boundary 430 can provide sufficient width to provide a margin for misalignment of the phase etch opening. Without chrome boundary 430 defined, the mask will appear to have a dark line at the transition between phase zero and phase 180 during mask inspection, thus suggesting defects.

[0042] While the exemplary embodiments illustrated in the FIGURES and described above are presently preferred, it should be understood that these embodiments are offered by way of example only. Other embodiments may include, for example, different techniques for creating phase shifting regions. Furthermore, other embodiments may use phase angles other than 0 and 180 while still having a difference of 180. The invention is not limited to a particular embodiment, but extends to

various modifications, combinations, and permutations that nevertheless fall within the scope and spirit of the appended claims.